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BARK BEETLE RISK IN MATURE PONDEROSA PINE FORESTS IN WESTERN MONTANA

Philip C. Johnson

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COVER

Photograph taken on a study plot in the Piquett Creek Experimental Area, Bitterroot National Forest, Montana, shows a mature ponderosa pine forest; in the background is Boulder Peak, elevation 9,650 feet.

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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Forest Service
U.S. Department of Agriculture
Ogden, Utah 84401
Robert W. Harris, Director

ABSTRACT

The Ponderosa Pine Risk Rating System developed in California was studied in western Montana to determine whether it could effectively identify individual mature trees most frequently killed by the western pine beetle, Dendroctonus brevicomis LeConte, or the mountain pine beetle, D. ponderosae Hopkins (Coleoptera: Scolytidae).

Risk 3 and Risk 4 trees--the high risk trees of the four-rating system--comprised 20 percent of the board-foot volume of 12,000 merchantable, risk rated ponderosa pine trees at 35 localities. On study plots in 22 of these localities, ponderosa pine stands that remained undisturbed throughout the study initially contained 17 percent of their total pine volume in Risk 3 and Risk 4 trees. Risk 3 and Risk 4 trees, however, made up 76 percent of the volume of all ponderosa pine trees killed by populations of the two pine beetles on these plots during the study.

Ponderosa pine mortality from the two pine beetle species was consistently low during the study, amounting to a mean of only 15.5 board feet per acre per year on the 22 undisturbed study plots--an amount considerably less than the estimated gross ponderosa pine increment on the same plots.

Subsidiary information obtained from the study indicated that (1) external crown characteristics used by the risk rating system in California to delineate the risk of mature ponderosa pine trees to attack by the western pine beetle were equally effective for this purpose in western Montana; (2) Risk 3 and Risk 4 ponderosa pine trees, together, grew an average of 0.18 inch radially during one 10-year period of the study, and Risk 1 and Risk 2 pine trees grew an average of 0.43 and 0.31 inch, respectively; (3) in 15 mature ponderosa pine stands where soil characteristics were measured, Risk 3 and Risk 4 trees were progressively more abundant as the fertility, productivity, and water-holding capacity of the soils declined; and (4) the mountain pine beetle was not an important primary killer of mature ponderosa pine trees during the study, and it exerted little influence in predisposing low risk trees to attack by the western pine beetle.

It was concluded from the study that managers of mature ponderosa pine forests in western Montana can use the risk rating system to assess the susceptibility of these forests, or of individual ponderosa pine trees in them, to lethal attacks of the western pine beetle for 10 years or more during periods of endemic beetle populations.

CONTENTS

Old-growth stand of ponderosa pine on the McCrea Park risk rating plot near Alberton, Montana. The crowns of the overmature trees in this relatively dense stand exhibit varying decline in vigor symptomatic of increasing susceptibility of some trees to lethal attacks of the western pine beetle.

INTRODUCTION

During the 1940's, managers of ponderosa pine forest properties in the northern Rocky Mountain States displayed increasing interest in the possibility of using sanitation-salvage cuttings to prevent destructive outbreaks of the western pine beetle, *Dendroctonus brevicomis* LeConte (Coleoptera: Scolytidae). Their interest possibly stemmed from reports of tests and several operational applications of such cuttings made during the late 1930's in ponderosa pine forests in northeastern California and eastern Oregon wherein the cuttings were credited with reducing intolerable tree mortality from the pine beetle. During the mid-1930's, in this northwest fringe of the North American Great Basin, the concept of preventive control of the western pine beetle had become a reality as a result of the development of the sanitation-salvage cutting method (Bongberg;[1] Johnson;[2] Keen and Salman 1942; Orr 1942; Salman and Bongberg 1942).

Forest entomologists coined the term "sanitation-salvage cutting" to refer to a light silvicultural selection cutting designed to remove from overstory stands for utilization certain merchantable ponderosa pine trees judged to be potential breeding habitats for the western pine beetle. These trees are ordinarily of low vigor and readily identified as the Risk 3 or Risk 4 trees of the four-rating Ponderosa Pine Risk Rating System (see fig. 1) evolved by Salman and Bongberg (1942). Under this rating

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[1]J. W. Bongberg. Effectiveness of sanitation-salvage logging in reducing insect-caused loss, Blacks Mountain Experimental Forest, season of 1940. USDA Bur. Entomol. and Plant Quar., Forest Insect Lab., Berkeley, Calif. Unpub. Rep. May 12, 1941.

[2]Philip C. Johnson. Effect of sanitation-salvage cutting upon subsequent insect-caused pine mortality, Blacks Mountain Experimental Forest, progress report, 1937-1943. USDA Bur. Entomol. and Plant Quar., Forest Insect Lab., Berkeley, Calif. Unpub. Rep. May 31, 1946.

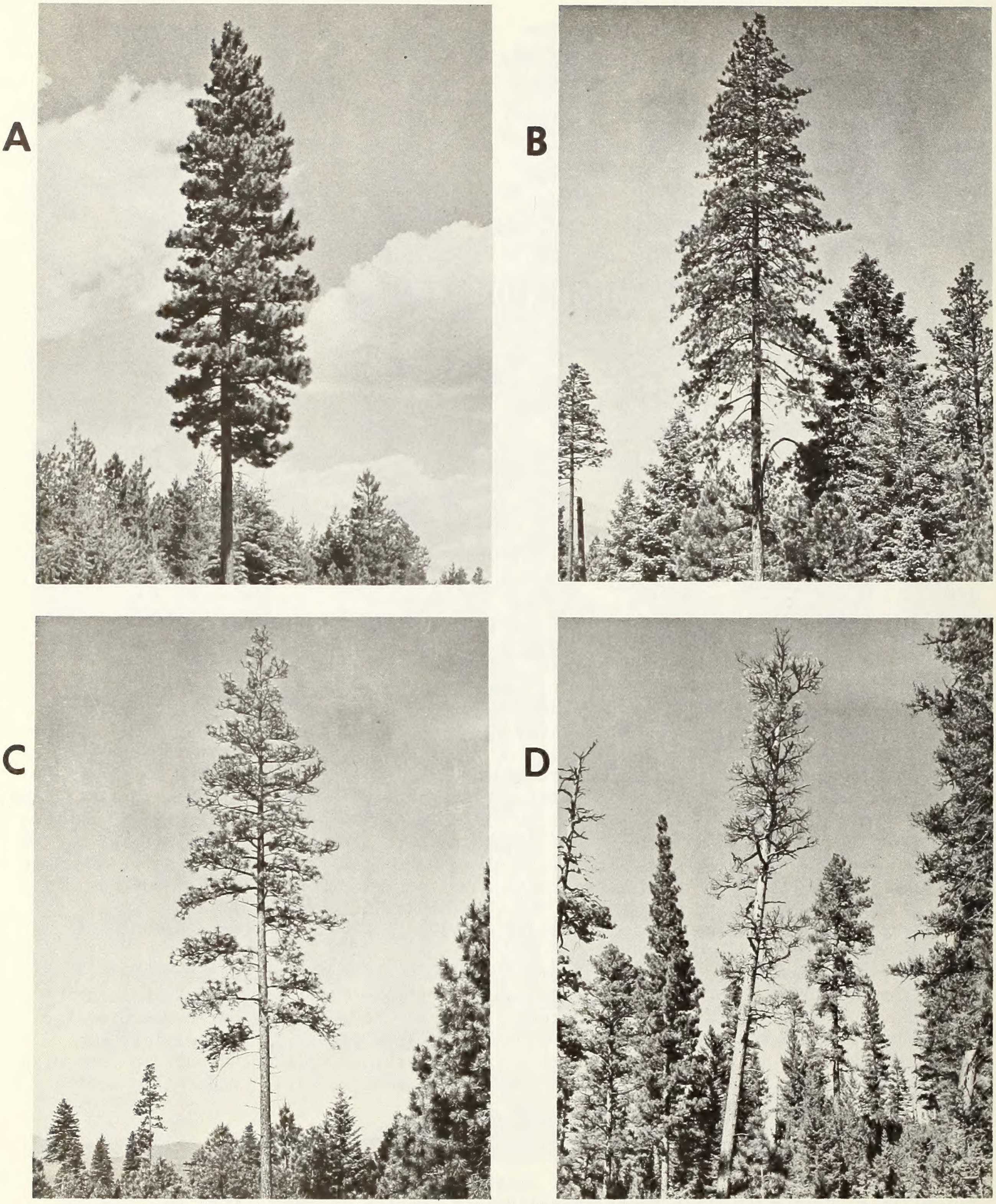

Figure 1.--Crown characteristics of ponderosa pine trees symbolizing each of the four ratings of the Ponderosa Pine Risk Rating System and the relative risk, or susceptibility, of trees in each rating to attacks by the western pine beetle: A, Risk 1 (low risk); B, Risk 2 (moderate risk); C, Risk 3 (high risk); and D, Risk 4 (very high risk).

system, such trees in northeastern California and eastern Oregon are rated as being either highly or very highly susceptible to lethal infestation by the pine beetle. Extensive tests made as late as 1959 have confirmed the capability of sanitation-salvage cuttings to minimize such destructive depletion of the ponderosa pine resource as occurred during the period from 1940 to 1959 in northeastern California and eastern Oregon (Keen and Miller 1960; Wickman and Eaton 1962).

Despite the apparent success of sanitation-salvage cuttings to control the pine beetle in the Pacific Coast States, several inherent differences in the ecology of ponderosa pine forests and the western pine beetle in the northern Rockies raised questions about use of such cuttings to achieve similar insect control benefits in this mountain region. Furthermore, ponderosa pine stands in the northern Rocky Mountains during the 1940's were experiencing environments favoring good tree vigor and growth. Almost nothing was known of the possible response of consequent endemic pine beetle populations to sanitation-salvage cuttings that might be applied as a control measure under these conditions.

However, this concern about the effectiveness of the cuttings was largely academic because information was not available on the adaptability in the northern Rockies of the Ponderosa Pine Risk Rating System upon which the cuttings relied. The rating system's effectiveness in identifying beetle susceptible trees to be removed from pine stands by the cuttings had to be determined before any tests of the cuttings as a beetle control measure could be undertaken in this region. To obtain this information, a study of the effectiveness of the risk rating system was undertaken in western Montana in 1948 by the Coeur d' Alene (Idaho) Forest Insect Laboratory of the former Bureau of Entomology and Plant Quarantine. The study was continued by the Intermountain Station until 1969.

In the study, we sought to determine (1) whether the western pine beetle has an affinity for attacking ponderosa pine trees classified as high risk, or beetle susceptible, using this rating system, (2) whether such attacks might be diverted by attractions created in low risk trees as a result of prior infestations in these trees by the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, or the pine engraver, *Ips pini* Say (Coleoptera: Scolytidae), or (3) whether the western pine beetle constituted a serious threat to mature ponderosa pine stands in the northern Rockies.

Endemic populations of the western pine beetle killed only minimal amounts of ponderosa pine timber during the 20-year span of the study. This and nearby harvest cuttings that made ecological islands of some of the study plots argued against further extensions of the study. Consequently, the study was terminated upon completion of tree mortality measurements of the 1968 beetle population.

EXPERIMENTAL PROCEDURE

Objectives of the study were to be achieved by annually measuring the mortality of ponderosa pine trees caused by the pine beetle over a 10-year period following the single initial risk rating of the trees. For this purpose, 35 plots having a combined net timbered area of 553 acres were established between 1948 and 1958 in widely scattered stands of virgin mature ponderosa pine in Montana west of the Continental Divide.

Financial limitations prevented the sampling of the heterogeneous pine stands in a manner that might statistically test the significance of possible differences in tree mortality rates in each of the several pine forest cover types of the Society of American Foresters (1954) or of the pine-dominating vegetation habitat types of Daubenmire and Daubenmire (1968) that might be represented in this region. Neither was it possible to make a sampling to determine possible differences in rates of beetle-caused tree mortality in relation to such stand factors as composition, density, or site indexes. These factors by themselves probably could not be used with sufficient accuracy to predict the amount of tree killing by the pine beetle in specific ponderosa pine stands as reported by Salman and Johnson.[3]

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[3]K. A. Salman and Philip C. Johnson. The forest insect hazard inventory of east-side forest areas, preliminary report on methods and their application. USDA Bur. Entomol. and Plant Quar., Forest Insect Lab., Berkeley, Calif. Unpub. Rep. Sept. 21, 1937.

Because of our concern with mature trees, the study plot stands were selected primarily on the basis of the descriptive qualities of their overstories. Reasonable homogeneity among plot stands was achieved by adopting minimal criteria for selecting them. They contained at least 10,000 gross board feet of ponderosa pine per acre in trees 11.1 inches in diameter breast height (d.b.h.) or larger. At least 50 percent of these trees were in the mature or overmature age classes of the Ponderosa Pine Tree Classification (Keen 1943). In effect, these were virgin, commercially operable pine stands.

All trees on the plots over 11.1 inches d.b.h. were measured and their gross board-foot volumes (Scribner scale) were later computed. Ponderosa pine trees on the plots were serially numbered, tagged for identification, risk rated, and classified by age and long-term vigor using the Ponderosa Pine Tree Classification. This provided a basis for the study of nearly 12,000 sawlog-size ponderosa pine trees containing a total gross volume of 9.3 million board feet. For phases of the study concerned only with the accumulated mortality of risk rated trees, this basis was reduced to 6,800 pine trees having a total volume of 4.8 million board feet on 270 acres because of experimental sanitation-salvage or random selection cuttings made on 12 of the plots during 1957 and 1958.

Stands on the plots were examined annually to locate and record the deaths of ponderosa pine trees caused by the western pine beetle or the mountain pine beetle during the previous year. To isolate and identify this source of tree killing, we recorded the deaths of trees caused by quick-acting lethal agents--windstorms, lightning, fire--or from other cambium-feeding insects[4] (Johnson 1966).

No fire-killed pine trees were reported during the study. Pine trees obviously killed by lightning or uprooted or lethally damaged by windstorms were recorded by their serial numbers and previously obtained dimensions and descriptions. Pine trees apparently killed from other causes were felled and their boles were systematically examined to detect and record the presence and distribution of attacks, if any, of the two pine beetles or of other tree-killing, cambium-feeding insects (Johnson 1967). Knowledge of the biology and phenology of the various insects involved was a requisite of the bole examinations. It was possible to identify the insect or insects that were infesting each tree bole and to determine which of them was probably responsible for the immediate death of the tree from (1) the observed progress of the construction of parent beetle egg galleries and larval mines, and (2) the metamorphic stages of the insects present.

The risk rating's concern with tree vigor suggested an investigation of soils on the study plots to determine whether a relationship existed between the presence of certain soil characteristics and the abundance of high risk trees in the plot stands. At the request of the Intermountain Station, soils on 15 of the risk rating plots were classified by the Soils Management Branch, Division of Soils and Watershed Management Branch, Northern Region, USDA Forest Service. A brief description of the methods used is quoted here from the report[5] of the completed classification:

> The soils on 15 research plots in western Montana were examined in the field. Preliminary identification of the soils was made. The relative depth and texture of the soils were particularly noted because they are

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[4]Notably, the pine engraver, *Ips pini* Say, or the California flatheaded borer, *Melanophila californica* Van Dyke (Coleoptera: Buprestidae).

[5]R. C. McConnell. Correlation between soils and bark beetle susceptibility classes for ponderosa pine stands, western Montana research plots. Unpub. Rep., USDA Forest Serv., Northern Region, Missoula, Montana. 6 p. 1966.

associated and express the potential storage of moisture. Higher storage of moisture should be associated with higher tree vigor and lower beetle risk susceptibility class. Indicators of soil depth and texture can be secured by observing land forms, kinds of materials underlying the soil, observations of deep road cuts, uprooted trees, mapping experience in the general area, and published soil survey reports. Important preliminary qualitative data on soils was quickly collected and first stratification of data was made. For qualitative determination of soil moisture it is expected that pits would eventually be dug in the plots, the soil profile described in detail, and samples taken for laboratory determination of moisture points, and fertility factors. At that time, detailed mapping of soil in the plots would be made in order to check soil uniformity and variation.

Another facet of the study sought information on the radial growth rates of mature ponderosa pine trees representing different risk ratings. This was done cooperatively with the School of Forestry of the University of Montana. Increment cores were extracted from 383 risk rated ponderosa pine trees at breast height on four plots. Mean tree ring widths for the last 10 years (1944-1953) were calculated for cores representing each risk rating group and comparisons were made of these means.

By 1958 it was apparent that objectives of the study could not be attained within 10 years because of continuing low levels of pine tree mortality that resulted from the endemic populations of the western pine beetle and the mountain pine beetle that persisted during the period. By agreement with cooperators, the study was continued for a second 10-year period. Hopefully, tree mortality from the two pine beetles would be sufficient at the end of this extended period to realize objectives of the study.

Extending the study posed a new question. Would the initial risk ratings continue to be valid during the second 10 years of the study? Changes in the initial risk ratings of some pine trees had been noted by research personnel throughout the first 10 years of the study. To ensure valid ratings during the second 10 years, the pine trees on 17 plots established before 1952 were re-rated in 1964 and 1965. This was done by trained forestry research technicians under the close supervision of the research entomologist in charge of the study. This procedure hopefully afforded continuity as well as a minimum of personal bias in the ratings.

DESCRIPTIONS OF THE PLOT OVERSTORY STANDS

Measurements revealed that the structural and ecological values of the predominantly ponderosa pine overstory stands varied among the plots and, to a lesser degree, within the plots. These values substantiated the long-observed variability of mature ponderosa pine stands in mountainous western Montana. Here, rapidly changing topography is responsible for complex mosaics of plant habitats that not only produce innumerable combinations of vegetation habitat types within relatively small areas but also variations in the productive capabilities of plants within these types (fig. 2). The differing combinations of descriptive values represented by the plot stands undoubtedly are repeated many times in stands of mature ponderosa pine throughout western Montana. It is almost certain, too, that many pine stands in this geographic area possess combinations of values not represented by the plot stands.

Forest Cover and Vegetation Habitat Types

Of the 35 plots used to sample ponderosa pine stand conditions, only six contained stands that represented the Society of American Foresters' interior ponderosa pine forest cover type (S.A.F. Type 237) in which ponderosa pine is strongly climax. This may indicate the relative sparseness of this type of pine stand in western Montana.[6] Most of the remaining plot stands represented the Society's ponderosa pine--larch--Douglas-fir forest cover type (S.A.F. Type 214) wherein ponderosa pine is strongly seral.

The plot stands represented several of the Daubenmires' vegetation habitat types. Although these types were developed from vegetation mosaics in eastern Washington and northern Idaho, current ecological studies indicate that some of them containing significant amounts of ponderosa pine are to be found in limited amounts in western Montana.[6] Among them are the *Pinus ponderosa/Festuca idahoensis* (ponderosa pine/Idaho fescue), *Pinus ponderosa/Agropyron spicatum* (ponderosa pine/bluebunch wheatgrass), *Pinus ponderosa/Purshia tridentata* (ponderosa pine/bitterbrush), and the *Pinus ponderosa/Symphoricarpos albus* (ponderosa pine/snowberry) types in which ponderosa pine is climax.

[6] Robert D. Pfister, Research Forest Ecologist, and Peter F. Stickney, Research Range Ecologist, Forestry Sciences Laboratory, Missoula, Montana. Personal communication.

Figure 2.--The heterogeneity of old-growth ponderosa pine stands in western Montana is illustrated here. Abrupt topography and occasional catastrophic fires, insect outbreaks, or windstorms are responsible for frequent changes in site conditions over relatively small areas and a resultant lack of continuity in the forest vegetation.

They also include the *Pseudotsuga menziesii/Calamagrostis rubescens* (Douglas-fir/pinegrass), *Pseudotsuga menziesii/Physocarpus malvaceus* (Douglas-fir/ninebark), and the *Pseudotsuga menziesii/Symphoricarpos albus* (Douglas-fir/snowberry) types in which ponderosa pine is seral. Roe[7] is of the opinion that some of the most productive stands of ponderosa pine in western Montana are to be found in some of these Douglas-fir habitat types.

Composition and Density

Overstory trees on 12 plots were exclusively ponderosa pine; however, the species probably was climax on no more than half of these plots. In contrast, 27 percent of all overstory trees and 11 percent of their gross board-foot volume on the remaining 23 plots were species other than ponderosa pine.

The most prevalent of these nonpine tree species was Rocky Mountain Douglas-fir, *Pseudotsuga menziesii* var. *glauca* (Beissner) Franco. This was followed by lodgepole pine (*Pinus contorta* Douglas) and western larch, (*Larix occidentalis* Nuttall), which occurred only sparsely on some plots.

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[7]Arthur L. Roe. Formerly, Research Silviculturist, Intermountain Station, Ogden, Utah. Personal communication.

Figure 3.--Dense stand of advanced reproduction of Rocky Mountain Douglas-fir under a well-stocked overstory of mature ponderosa pine on a risk rating plot in the Piquett Creek Experimental Area, Bitterroot National Forest, Montana.

The seral nature of ponderosa pine in most of the plot stands is only partially indicated by these nonpine tree species in the overstory. More conclusive evidence of ponderosa pine's serality in the plot stands is the intrusion in recent years of increasing amounts of nonpine reproduction in the understory stands of the plots. Dense stands of Rocky Mountain Douglas-fir, in particular, now occupy the ground under the pine canopy on parts of some plots (fig. 3). Stimulated by effective control of wildfires and by growing conditions that have favored nonpine species during the past three decades, resultant nonpine reproduction is preventing or crowding that of ponderosa pine in many of the plot stands.

Observations disclosed that the pine understory on most of the plots was so sparse that its maturation will produce timber yields far short of those expected from ponderosa pine site indexes 70, 80, or 90 that the plots represent (Meyer 1938).

The mean stocking density for all species ranged for each plot stand from 14.7 to 44.9 trees per acre (12,920 to 25,730 gross board feet per acre). The mean stocking density for ponderosa pine alone ranged for each plot stand from 14.7 to 37.3 trees per acre (9,990 to 25,200 gross board feet per acre) (fig. 4). The stocking densities for pine and nonpine species are shown for each of the 35 plots in tables 1 and 2.

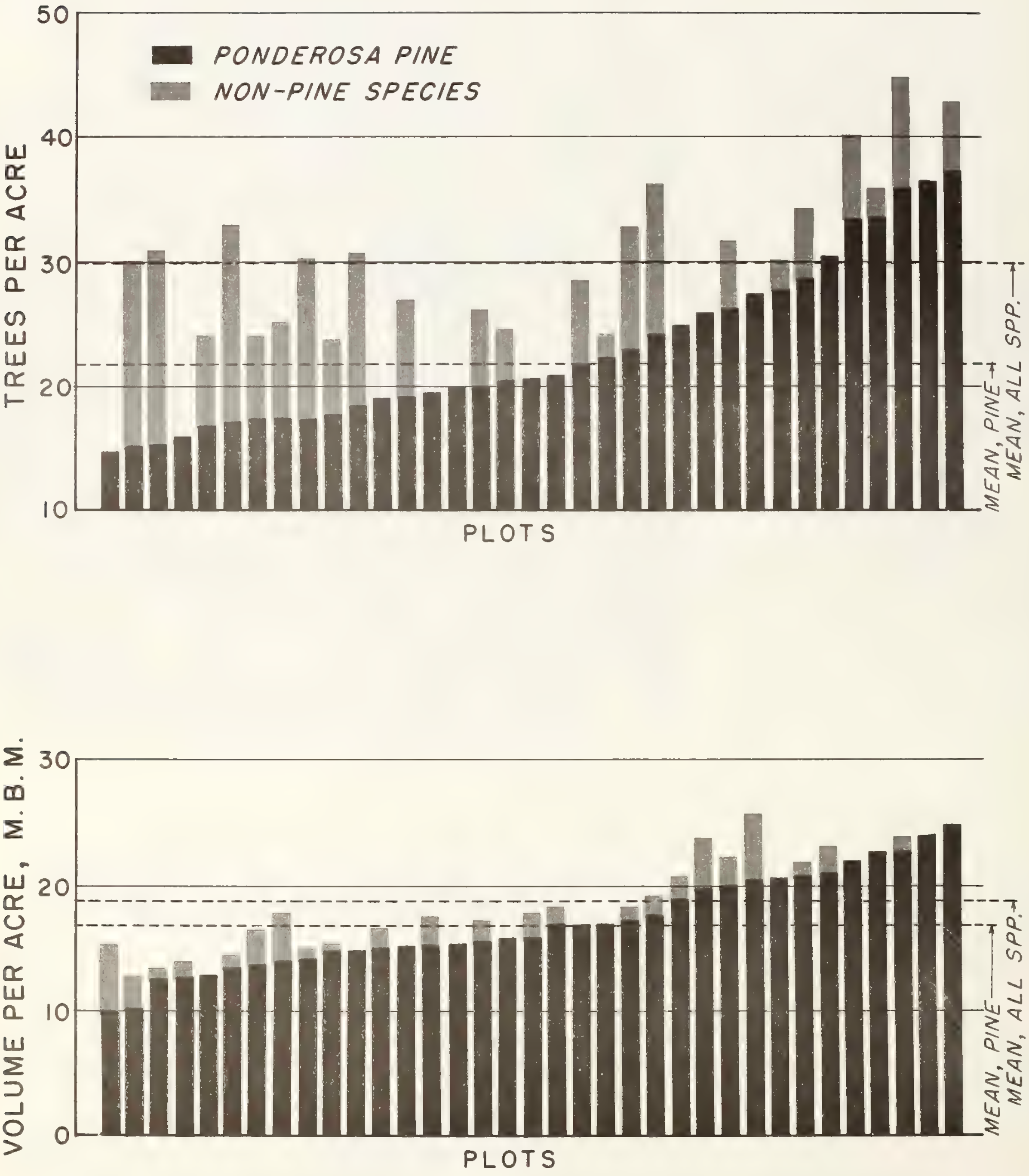

Figure 4.--Variation in the mean number and gross board-foot volume of overstory sawlog-size ponderosa pine trees per acre on 35 plots in western Montana. The horizontal position of the plots is not necessarily the same in the upper and lower histograms.

Table 1.--*Number of trees 11.1 inches d.b.h. or greater per acre in initial plot stands by species*

Owner/Plot	Total timbered area	Ponderosa pine	Lodgepole pine	Douglas-fir	Western larch	Total, all species
Anaconda Forest Products						
Lincoln	12.0	17.4	--	15.9	--	33.3
Fish Creek Forks	10.0	22.4	--	1.2	0.9	24.5
McCrea Park[1]	7.0	17.1	0.3	1.3	5.4	24.1
Longpre Cabins	8.9	37.3	--	4.8	.7	42.8
Fishtrap Creek	10.0	33.8	--	2.3	--	36.1
Little Thompson River	10.0	26.5	5.2	.2	.1	32.0
North Fork Little Thompson River	10.0	33.6	3.7	1.2	1.6	40.1
Pleasant Valley	10.0	36.6	--	--	--	36.6
Jake Little Ranch	10.0	27.9	--	--	--	27.9
Lost Prairie	10.0	30.7	--	--	--	30.7
Lake McGregor	8.5	35.8	.8	4.1	3.9	44.6
Glacier Park Company						
Little Bitterroot River	10.0	28.9	--	5.5	--	34.4
St. Regis Paper Co.						
Loon Lake	5.4	27.7	--	--	--	27.7
Bitterroot National Forest						
Bear Creek Saddle	8.4	20.6	--	4.1	--	24.7
Overwhich Creek	10.0	25.1	.3	.2	--	25.6
Piquett Creek B[2]	22.0	19.7	--	10.1	--	29.8
D[2]	22.0	16.2	--	10.1	--	26.3
G[2]	22.6	20.8	--	10.1	--	30.9
J[2]	22.6	26.1	--	10.1	--	36.2
O[2]	15.8	14.7	--	10.1	--	24.8
Q[2]	22.5	21.1	--	10.1	--	31.2
C[3]	22.7	17.5	--	9.4	--	26.9
F[3]	24.0	20.2	--	6.0	--	26.2
H[3]	22.2	18.0	--	4.4	--	22.4
K[3]	22.5	24.2	--	4.6	--	28.8
L[3]	21.3	18.5	--	12.7	--	31.2
P[3]	22.5	15.3	--	10.1	--	25.4
A[3]	22.4	15.2	--	14.9	--	30.1
E[3]	22.2	23.4	--	10.0	--	33.4
I[3]	21.9	19.4	--	7.7	--	27.1
M[3]	23.7	21.9	--	7.0	--	28.9
N[3]	22.5	17.4	--	6.9	--	24.3
R[3]	22.5	17.5	--	3.9	--	21.4
Helena National Forest						
Lincoln 9.7	9.7	21.7	1.1	--	--	22.8
Kootenai National Forest						
Rexford 5.0	5.0	19.4	--	--	--	19.4

[1]Timber is located partially on Lolo National Forest.
[2]Control plots.
[3]Prior to cutting.

Table 2.--*Gross board-foot volumes of trees 11 inches or greater per acre in initial plot stands by species*

Owner/Plot		Ponderosa pine	Lodgepole pine	Douglas-fir	Western larch	Total, all species
Anaconda Forest Products						
Lincoln		9,991	--	5,443	--	15,434
Fish Creek Forks		13,636	--	102	754	14,492
McCrea Park[1]		20,590	23	360	4,759	25,732
Longpre Cabins		12,550	--	499	245	13,294
Fishtrap Creek		14,353	--	646	--	14,999
Little Thompson River		14,852	557	20	45	15,474
North Fork Little Thompson River		15,616	464	451	787	17,318
Pleasant Valley		24,098	--	--	--	24,098
Jake Little Ranch		18,839	--	--	--	18,839
Lost Prairie		22,636	--	--	--	22,636
Lake McGregor		19,810	79	1,801	2,275	23,965
Glacier Park Co.						
Little Bitterroot River		15,800	--	2,250	--	18,050
St. Regis Paper Co.						
Loon Lake		16,722	--	--	--	16,722
Bitterroot National Forest						
Bear Creek Saddle		22,766	--	1,083	--	23,849
Overwhich Creek		25,198	24	8	--	25,230
Piquett Creek	B[2]	17,078	--	2,136	--	19,214
	D[2]	13,113	--	2,136	--	15,249
	G[2]	14,888	--	2,136	--	17,024
	J[2]	22,082	--	2,136	--	24,218
	O[2]	15,354	--	2,136	--	17,490
	Q[2]	15,749	--	2,136	--	17,885
	C[3]	12,739	--	1,610	--	14,349
	F[3]	17,245	--	1,129	--	18,374
	H[3]	15,046	--	1,664	--	16,710
	K[3]	15,429	--	884	--	16,313
	L[3]	20,031	--	2,409	--	22,440
	P[3]	14,052	--	2,106	--	16,158
	A[3]	10,389	--	2,580	--	12,969
	E[3]	21,129	--	2,167	--	23,296
	I[3]	16,666	--	1,776	--	18,442
	M[3]	19,161	--	1,532	--	20,693
	N[3]	20,834	--	1,242	--	22,076
	R[3]	13,716	--	1,057	--	14,773
Helena National Forest						
Lincoln		20,683	73	--	--	20,756
Kootenai National Forest						
Rexford		15,570	--	--	--	15,570

[1]Timber is located partially on Lolo National Forest.
[2]Control plots.
[3]Prior to cutting.

Pine Age Classes

Criteria used to select the ponderosa pine overstory stands on the 35 study plots assured that the stands would contain a mean of at least 10,000 gross board feet per acre in pine trees classified by the Ponderosa Pine Tree Classification as mature or overmature. The initial age class inventory of the nearly 12,000 sawlog-size ponderosa pine trees in the plot stands showed that 73 percent of them were in these two age classes as shown by the following tabulation:

Age classes	*Number of trees*	*Percentage of trees*
Young	466	3.9
Immature	2,735	22.9
Mature	3,536	29.6
Overmature	5,209	43.6
Total	11,946	100.0

JOHNSON, PHILIP C.

1972. Bark beetle risk in mature ponderosa pine forests in western Montana, USDA Forest Serv. Res. Pap. INT-119, 32 p.

Reports on results of a 20-year study on adaptability of the Ponderosa Pine Risk Rating System for identifying western pine beetle killing of mature trees in western Montana stands. Purpose was to ascertain whether sanitation-salvage cuttings could be used in such stands to control pine beetles with the same success as has been experienced in northeastern California and eastern Oregon.

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RISK RATINGS OF LIVING PONDEROSA PINE TREES

Procedures followed during the establishment of 553 acres of plots resulted in 11,946 sawlog-size ponderosa pine overstory trees being risk rated. The gross volume of these trees was 9,276,000 board feet. From this, it was possible to determine the number and volume of pine trees in each of the four ratings.

Distribution of Risk Rated Trees

Least abundant were trees rated Risk 1. These trees presumably are the least susceptible, or the most resistant, to attack by *Dendroctonus* bark beetles. They accounted for about 13 percent of the number and 8 percent of the volume, respectively, of the 11,946 risk rated pine trees (table 3). This paucity of low-risk trees also was discernible in each of the overstory stands of the 35 plots (table 4).

Trees rated Risk 2 (moderate) were by far the most abundant. Seventy-two percent of the number and volume of all the risk rated trees were in this category. Risk 2 trees, likewise, comprised a comparable proportion of risk rated trees in each of the plot stands (fig. 4).

Trees rated Risk 3 were considerably more abundant than those rated Risk 4 but, together, they made up 15 percent of the number and 20 percent of the volume, respectively, of the 11,946 risk rated trees (table 3). Risk 3 and Risk 4 trees, collectively, are the "high risk" trees of the risk rating system. They are the trees that sanitation-salvage cuttings are designed to remove from ponderosa pine stands to prevent the buildup in these stands of epidemic populations of bark beetles.

Table 3.--*Distribution by risk ratings of pooled sawlog-size ponderosa pine trees on 35 plots in western Montana* [1]

Risk ratings	Number of trees	Percent of total number	Gross volume (board feet)	Percent of total volume
1 (Low)	1,536 (2.8)	12.9	787,260 (1,424)	8.5
2 (Moderate)	8,628 (15.6)	72.2	6,640,970 (12,009)	71.6
3 (High)	1,533 (2.8)	12.8	1,583,390 (2,864)	17.1
4 (Very high)	249 (0.4)	2.1	264,740 (478)	2.8
Total	11,946 (21.6)	100.0	9,276,360 (16,775)	100.0

[1]Figures in parentheses represent per-acre values based on a combined total of 553 acres for the 35 plots.

Table 4.--*Number of ponderosa pine trees 11.1 inches d.b.h. or greater per acre in initial plot stands classified according to bark beetle risk ratings*

Owner/Plot	Risk rating 1	2	3	4
Anaconda Forest Products				
Lincoln	2.5	14.1	0.7	0.1
Fish Creek Forks	8.7	11.0	2.3	.4
McCrea Park[1]	2.7	11.8	2.3	.3
Longpre Cabins	9.9	23.5	3.0	.9
Fishtrap Creek	14.5	16.4	2.7	.2
Little Thompson River	4.7	19.4	2.2	.2
North Fork Little Thompson River	7.7	20.6	4.4	.9
Pleasant Valley	4.0	29.9	2.2	.5
Jake Little Ranch	4.3	20.0	3.0	.6
Lost Prairie	10.9	17.9	1.7	.2
Lake McGregor	6.7	27.0	2.1	.0
Glacier Park Co.				
Little Bitterroot River	4.8	17.9	4.8	1.4
St. Regis Paper Co.				
Loon Lake	14.5	11.3	1.5	.4
Helena National Forest				
Lincoln	5.6	12.7	1.7	.0
Kootenai National Forest				
Rexford	1.1	13.6	3.4	1.2

Owner/Plot		Risk rating 1	2	3	4
Bitterroot National Forest					
Bear Creek Saddle		1.5	14.0	4.6	0.5
Overwhich Creek		7.7	13.8	3.0	.6
Piquett Creek	B[2]	.8	16.0	2.6	.2
	D[2]	.5	12.8	2.7	.1
	G[2]	1.5	17.3	1.9	.1
	J[2]	1.4	21.0	3.6	.1
	O[2]	1.3	11.7	1.6	.2
	Q[2]	3.3	15.6	2.1	.1
	C[3]	3.2	11.8	2.4	.1
	F[3]	.4	17.1	2.3	.4
	H[3]	1.1	13.9	2.6	.4
	K[3]	.9	16.7	5.3	1.3
	L[3]	.8	11.3	4.8	1.6
	P[3]	2.0	11.7	1.5	.1
	A[3]	.2	12.4	2.4	.2
	E[3]	.7	18.6	3.5	.6
	I[3]	1.3	15.7	2.2	.4
	M[3]	.9	17.1	3.2	.7
	N[3]	.2	13.7	2.6	.9
	R[3]	2.6	11.3	3.2	.5

[1]Timber is located partially on Lolo National Forest.
[2]Control plots.
[3]Prior to cutting.

On the basis of the 553 acres of the 35 plots, Risk 3 and Risk 4 trees together averaged 3.2 trees and 3,342 board feet per acre. The mean per-acre volume of these high risk trees varied in each of the 35 plot stands, but it was less than 2,000 board feet in only eight of these stands (table 5).

Risk 3 and Risk 4 trees together represented 14.9 percent of the 11,946 mature ponderosa pine trees measured during the study; their total volume constituted 19.9 percent of all measured pine trees. These percentages, too, varied among the 35 plot stands (fig. 5).

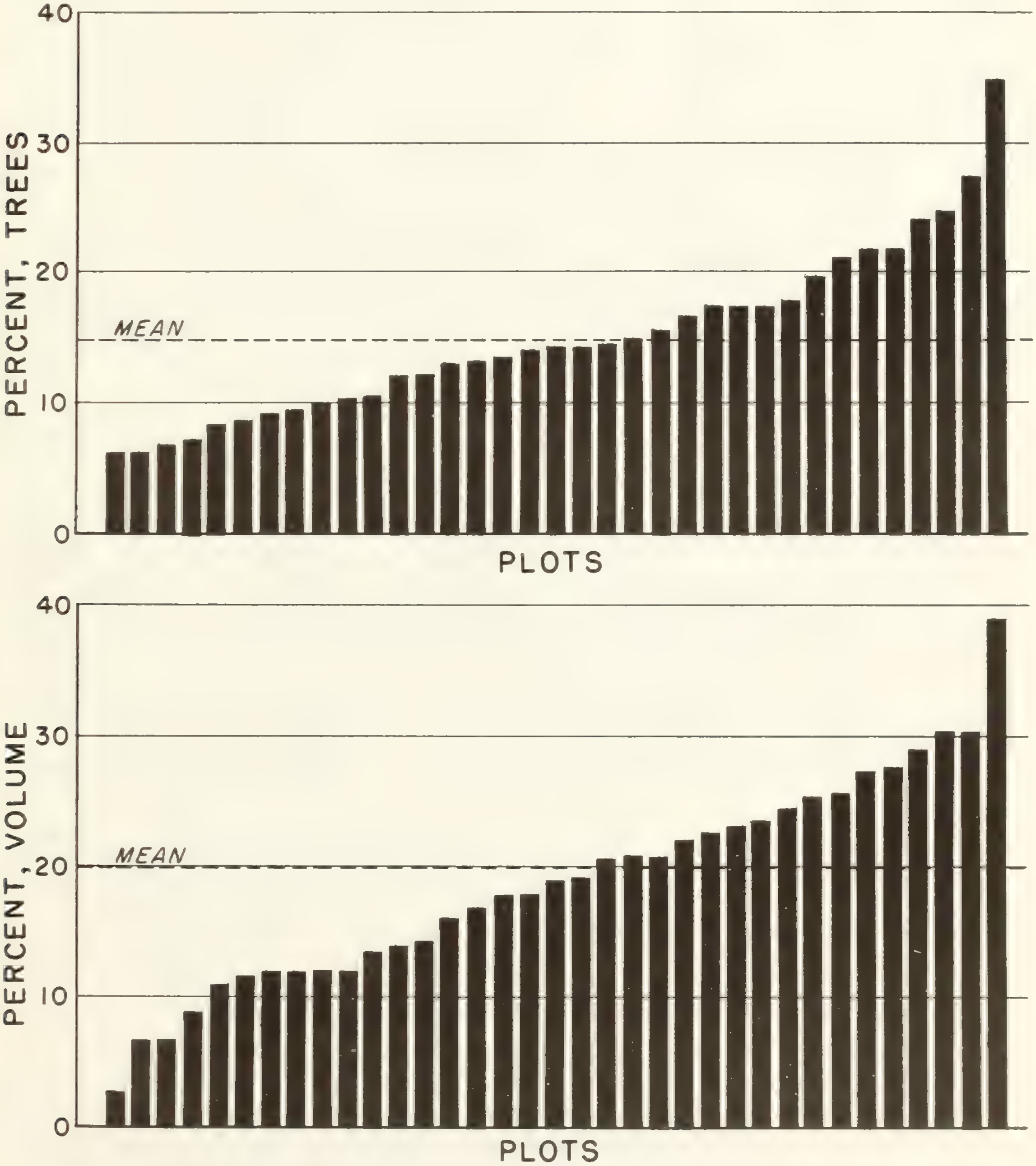

Figure 5.--Variation in the percentage of pooled Risk 3 and Risk 4 trees in overstory stands of mature ponderosa pine on 35 plots in western Montana. The horizontal position of the plots is not necessarily the same in the upper and lower histograms.

Table 5.--*Gross board-foot volume of ponderosa pine trees 11.1 inches d.b.h. or greater per acre in initial plot stands classified according to bark beetle risk ratings*

Owner/Plot	Risk Rating 1	Risk Rating 2	Risk Rating 3	Risk Rating 4
Anaconda Forest Products				
Lincoln	1,493	8,240	230	28
Fish Creek Forks	1,467	8,720	3,046	403
McCrea Park[1]	5,417	12,933	2,070	170
Longpre Cabins	1,937	8,829	1,445	339
Fishtrap Creek	2,110	9,693	2,438	112
Little Thompson River	1,369	11,416	2,014	53
North Fork Little Thompson River	1,310	10,897	2,721	688
Pleasant Valley	2,722	19,787	1,383	206
Jake Little Ranch	1,932	12,589	3,057	1,261
Lost Prairie	5,209	14,369	2,631	427
Lake McGregor	2,694	14,842	2,256	18
Glacier Park Co.				
Little Bitterroot River	1,513	10,423	3,222	642
St. Regis Paper Co.				
Loon Lake	6,136	8,620	1,862	104
Helena National Forest				
Lincoln	4,116	14,050	2,517	0
Kootenai National Forest				
Rexford	916	11,718	2,150	790

Owner/Plot		Risk rating 1	Risk rating 2	Risk rating 3	Risk rating 4
Bitterroot National Forest					
Bear Creek Saddle		916	16,024	5,546	280
Overwhich Creek		7,318	15,150	2,574	156
Piquett Creek	B[3]	726	13,121	2,877	354
	D[3]	254	8,909	3,780	170
	G[3]	1,114	12,006	1,665	103
	J[3]	1,071	16,488	4,472	51
	O[3]	2,028	11,494	1,632	200
	Q[3]	1,768	12,076	1,876	29
	C[4]	1,983	8,099	2,608	48
	F[4]	156	14,356	2,309	424
	H[4]	151	10,768	3,644	483
	K[4]	263	10,519	3,579	1,067
	L[4]	730	11,497	5,504	2,301
	P[4]	2,027	10,765	1,096	164
	A[4]	28	7,345	2,837	179
	E[4]	270	16,063	4,276	520
	I[4]	1,058	12,819	2,513	276
	M[4]	673	14,272	3,119	1,097
	N[4]	180	14,915	4,118	1,621
	R[4]	1,980	8,509	2,678	549

[1]Timbered acreage shown on table 1.
[2]Timber is located partially on Lolo National Forest.
[3]Control plots.
[4]Prior to cutting.

Table 6.--*Relationship between the abundance of high risk ponderosa pine trees and some soil characteristics in western Montana*

Number of plots	Percentage of Risk 3 and Risk 4 trees in the stand	Soil fertility rating class[1]	Soil productivity site index[2]	Water-holding capacity[3]
				Inches
5	7-12	1	66-71	12-16
4	13-18	2	54-71	6-12
2	19-21	3	54-60	5-6
4	22-25	3-4	54	5-6

[1]Relative rating of soils between plots; based on chemical and physical properties of the soils and their ability to supply plant nutrients. Class 1, high; classes 2 and 3, moderate; class 4, low.

[2]A measure of productivity under specified management practices. Tree height at 100 years (Meyer 1938). Correlated with information from Cox and others (1960).

[3]As measured in top 5 feet of soil.

Risk Ratings and Soil Characteristics

The preliminary method of soil examination used by McConnell[8] on 15 of the plots in 1966 disclosed that the incidence of high risk pine trees in the sampled plot stands was associated with several soil characteristics. Increasing percentages of pooled Risk 3 and Risk 4 trees were closely related to (1) decreasing soil fertility rating classes, (2) soil productivity site classes, and (3) inches of water-holding capacity in the top 5 feet of soil (table 6).

A general relationship was indicated between the abundance of high risk trees and the following factors observed or measured in the preliminary soil examinations: (1) Soil depth to gravel-sand or bedrock; (2) texture of profile; (3) underlying soil material; and (4) related soil series.

No apparent relationship was indicated between the abundance of high risk trees and the following factors: (1) Depth to water table; (2) elevation, slope, or exposure; (3) landform; (4) mean annual precipitation or F-degree temperatures of the nearest meteorological station; (5) precipitation-evaporation transpiration index; or (6) windthrow and windthrow physiography.

Risk Ratings and Tree Growth Rates

The increment cores taken from basal bole sections of the 383 trees were measured for the years 1944 to 1953, the most recent 10-year growth period. The mean cumulative width of the annual rings for the period, 1944 to 1953, was calculated in inches for each core group on each plot. The value derived is expressed as the mean 10-year cumulative radial increment.

[8]Op. cit.

Table 7.--*Comparison of the mean 10-year cumulative radial increment between mature ponderosa pine trees of different risk ratings in western Montana*

Plot	Number of trees sampled	Mean increment		
		Risk 1 trees	Risk 2 trees	Risks 3 and 4 trees[1]
		- - - - - - - - - - - *Inch* - - - - - - - - - - -		
A	212	0.37	0.23	0.15
B	90	.43	.36	.19
C	38	.49	.35	.19
D	43	.43	.30	.20
Average		.43	.31	.18
Number of trees in Risk group(s)		143	168	72

[1]These two ratings were pooled for statistical analyses.

When compared with data reported by Spencer (1953), these means exhibited a progressive decline in value from trees rated Risk 1 to those of the pooled Risk 3 and Risk 4 trees (table 7). This statistically significant reduction in growth rates confirmed the poor vigor of trees rated Risk 3 and Risk 4. This reduction had been suspected because the risk rating system identifies trees having weakened or decadent crowns.

Mean Volumes of Risk Rated Trees

The mean gross volume of the 11,946 sawlog-size risk-rated trees was 776 board feet. The mean volume of Risk 1 and Risk 2 trees was less than this value; that of Risk 3 and Risk 4 trees exceeded it, as shown in the following tabulation:

Risk ratings	*Number of risk rated trees*	*Volume of risk rated trees (Board feet)*	*Mean volume per tree (Board feet)*
1 (Low)	1,536	787,260	512
2 (Moderate)	8,628	6,640,970	770
3 (High)	1,533	1,583,390	1,033
4 (Very high)	249	264,740	1,063
Total	11,946	9,276,360	776

CAUSES OF PINE TREE KILLING

The killing of mature ponderosa pine trees from several causes was measured on 22 plots that retained undisturbed virgin stands throughout the study. The timber stands on these plots were not subjected at any time to ground fires, flooding, or other environmental disturbances that would cause the death of ponderosa pine trees within 1 year or less.

Measurements from the 22 plots recorded the death during the study of 366 mature ponderosa pine trees having a combined volume of 308,810 board feet (table 8). They were killed by attacks of *Dendroctonus* bark beetles, lightning strikes, other cambium-feeding insects, windstorms, or unknown causes.

Similar measurements of ponderosa pine mortality from 13 other plots used for portions of the study are not reported here. The stands on these latter plots were lightly cut under several experimental tree selection systems soon after the plots were established. The cuttings were made to determine if such treatments could influence the postcutting rate of ponderosa pine tree killing by bark beetles or other quick-acting lethal agents.

The uprooting or lethal breaking of trees by windstorms proved to be the greatest source of mortality: 52 percent of the 366 trees killed on the plots were from this source (table 8). Such killing occurred on almost all the plots each year, but several plots were subjected to catastrophic tree killing from two or three windstorms of hurricane force that swept through parts of western Montana during the study. On two plots (Loon Lake and Jake Little Ranch), the damage was so great that the usefulness of these plots ceased after 4 and 7 years, respectively (table 9).

Table 8.--*Cause and amount of ponderosa pine tree mortality from 1948 through 1968 on 22 plots not subjected to sanitation-salvage cuttings*[1]

Cause of tree mortality	Total mortality		Mortality per acre per year	
	Trees	Board feet	Trees	Board feet
Bark beetles	132	103,360	0.020	15.5
Lightning	16	29,330	.003	5.5
Other insects[2]	18	9,080	.002	1.8
Unknown	11	15,790	.002	2.7
Windstorms	189	151,250	.026	21.4
Total	366	308,810	.053	46.9

[1]See table 9 for number of years of records form each plot.
[2]Principally, the pine engraver (*Ips pini*) and the California flat-headed borer (*Melanophila californica*).

The next greatest source of pine tree killing was infestation by bark beetles. It also was the most consistently occurring form of mortality in the plot stands year after year (fig. 6). Bark beetles accounted for the death of 132 pine trees (36 percent of all the trees killed during the study).

Of these 132 trees, 124 were killed by the western pine beetle *(Dendroctonus brevicomis)* and eight by the mountain pine beetle *(Dendroctonus ponderosae)*. None of the trees killed by *Dendroctonus* beetles had been previously top-killed by the pine engraver *(Ips pini)*, nor was this form of damage to mature ponderosa pine trees observed in the plot stands.

Systematic bole analyses to determine the insect species responsible for the death of these trees indicated that the trees were killed by low level populations of attacking pine beetles. Not only were the attacks per square foot of bole bark surface relatively few, but the areas of infested cambium occupied by developing broods of these insects were scattered and likewise small. This provided ample habitat for secondary cambium-feeding insects to subsequently infest these same trees. Consequently, relatively large proportions of the available bole cambium of beetle-killed trees were infested by *Ips emarginatus* (LeConte), *Ips plastographus* (LeConte), and by assorted wood-boring beetles of the families Buprestidae and Cerambycidae (Johnson 1967).

Lightning, other cambium-feeding insects, and unknown causes together made up about 12 percent of the trees killed (fig. 7). For the most part, the occurrence of tree killing from these causes was sporadic and unpredictable as to their locale and timing.

Table 9.--*Cause and amount of cumulative ponderosa pine tree mortality from 1945 through [illegible] on the [illegible] study plots not subjected to sanitation-salvage cutting*

Plot[1]		No. of years of record	Bark beetles[2]		Lightning		Other insects[3]		Unknown		Windstorms		Total	
			No. of trees	Volume	No. of trees	Volume	No. of trees	Volume	No. of trees	Volume	No. of trees	Volume	No. of trees	Volume
				Bd. ft.		*Bd. ft.*		*Bd. ft.*		*Bd. ft.*		*Bd. ft.*		*Bd. ft.*
Fish Creek Forks		17	3	5,620					1	980	1	600		
McCrea Park		17	3	3,690	1	3,600			1	1,160	1	2,290		
Longpre Cabins		17	14	5,500							10	3,260		
Fishtrap Creek		17	5	1,580			1	50			2	660		
Little Thompson River		17	8	3,160	2	4,370	2	600	2	1,190	9	5,730		
North Fork Little Thompson River		17	14	10,290			7	6,070			5	3,230		
Pleasant Valley		17	2	1,180							49	39,030		
Jake Little Ranch		7	3	7,070							53	35,980		
Lost Prairie		17	1	1,910	4	5,280			2	6,040				
Lake McGregor		17	1	50					1	420	5	3,640		
Little Bitterroot River		17	9	6,340			3	980	1	1,160	9	9,150		
Loon Lake		4	7	3,230			1	180			18	15,630		
Rexford		20	3	1,680			2	620			3	2,860		
Bear Creek Saddle		17	4	2,890							2	2,210		
Overwhich Creek		17	4	3,000	1	2,790	1	530	1	980	6	8,760		
Lincoln		17	3	5,920	3	5,070								
Piquett Creek	B[4]	10	6	2,300	1	1,040					2	3,020		
	D[4]	10	3	2,120	1	2,250					2	2,490		
	G[4]	10	11	10,450	1	1,110			1	700	4	2,990		
	J[4]	10	16	14,000	1	1,390	1	50	1	3,160	2	1,580		
	O[4]	10	6	6,890							3	5,400		
	Q[4]	10	6	4,490	1	2,430					3	2,740		
Total			132	103,360	16	29,330	18	9,080	11	15,790	189	151,250	366	308,810
Weighted means/acre/year		14.2	0.020	15.5	0.003	5.5	0.002	1.8	0.002	2.7	0.026	21.4	0.053	46.9

[1]See table 1 for timbered acreage.

[2]Approximately 95 percent from infestations of the western pine beetle (*Dendroctonus brevicomis*) and 5 percent from those of the mountain pine beetle (*Dendroctonus ponderosae*).

[3]Principally from infestations of the pine engraver (*Ips pini*) and the California flatheaded borer (*Melanophila californica*).

[4]Control plots.

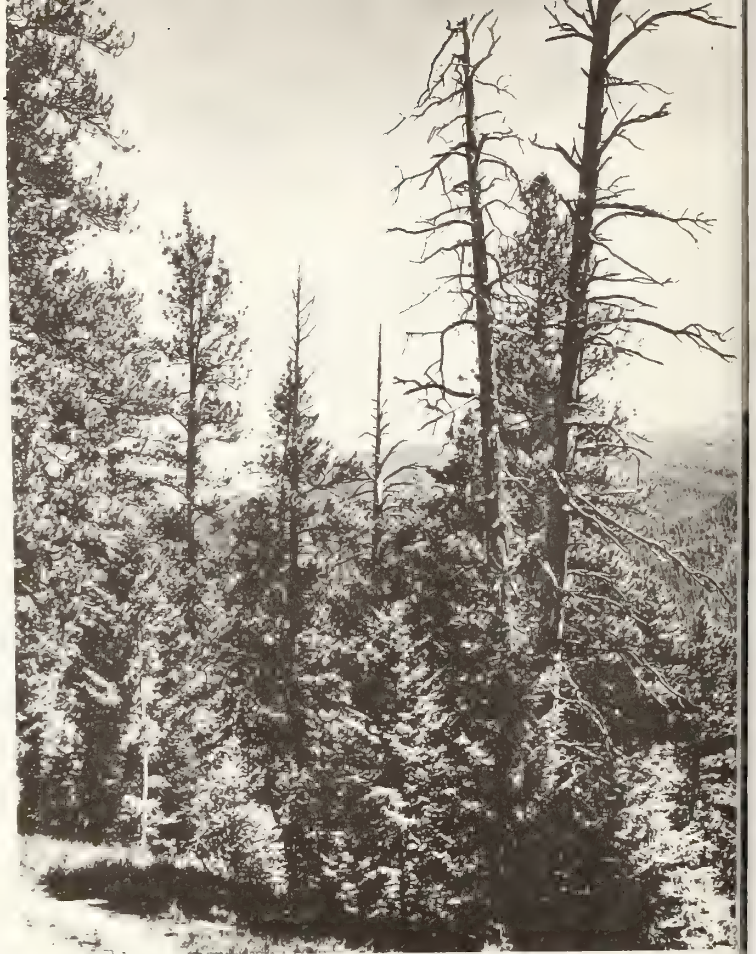

Figure 6.--Standing or fallen dead pine trees often are indisputable evidence of the severity of tree killing by the western pine beetle in past years throughout many old-growth ponderosa pine forests in western Montana. Loss of merchantable trees from even endemic populations of the pine beetle can be a significant cost factor in commercially managed ponderosa pine forests. It can be greater if nonpine tree species--such as Douglas-fir, shown here--swiftly usurp the ground surface under the former crown shadow of the dead pine trees, thus preventing establishment of often-desired seedlings of ponderosa pine.

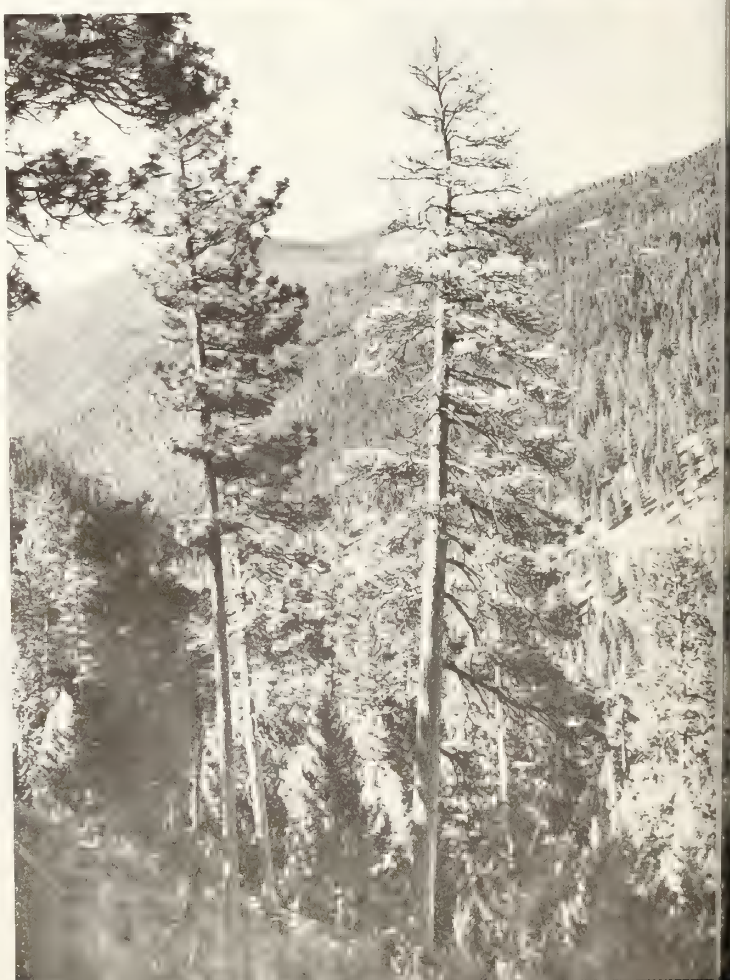

Figure 7.--This mature ponderosa pine tree dying on a risk rating plot in the Bitterroot National Forest, Montana, was struck by lightning during the spring of 1964 and heavily infested soon after by two successive generations of the western pine beetle. While the tree might have survived the lightning strike, it could not have survived the excessively numerous attacks of the pine beetle. Ponderosa pine trees occasionally struck by lightning in western Montana are usually dominant, vigorous, low-risk trees presumably resistant to attackc of the pine beetle. Once they are struck by lightning, however, they become highly attractive for a year or two as a breeding habitat for the beetle.

RISK RATINGS OF BEETLE-KILLED PONDEROSA PINE TREES

Approximately three of every four of the 132 ponderosa pine trees killed by *Dendroctonus* bark beetles on the plots since the start of the study were either Risk 3 (high risk) or Risk 4 (very high risk) trees (see table 10). The proportion of the high risk trees (Risk 3 and Risk 4 together) among the total number of beetle-killed pine trees varied from plot to plot. In 20 of the 22 plots, however, high risk beetle-killed trees exceeded low risk beetle-killed trees (Risk 1 and Risk 2 together) both in their number and board-foot volume (table 11).

From the pooled data in table 10, it is evident that Risk 2 trees were almost as numerous as Risk 4 trees among all the trees killed by pine beetles on the plots. The 38 Risk 2 trees, however, came from a substrate that was 39 times larger than that from which the 40 Risk 4 trees came (table 3). This suggests that Risk 4 trees would be killed by pine beetles sooner than an equal number of Risk 2 trees.

Table 10.--*Distribution by risk ratings of ponderosa pine trees killed by bark beetles from 1948 through 1968 on 22 plots not subjected to sanitation-salvage cuttings*

Risk ratings	Trees		Volume	
	Number	*Percent*	*Board feet*	*Percent*
1 (Low)	1	0.8	220	0.2
2 (Moderate)	38	28.8	24,520	23.7
3 (High)	53	40.1	43,800	42.4
4 (Very high)	40	30.3	34,820	33.7
Total	132	100.0	103,360	100.0

Table 11.--*Distribution by risk ratings of ponderosa pine trees killed by bark beetles from 1948 through 1968 on 22 study plots not subjected to sanitation-salvage cuttings*

Plot[1]		Risk I (Low)		Risk II (Moderate)		Risk III (High)[2]		Risk IV (Very high)[2]		Total	
		No. of trees[3]	Volume[4]	No. of trees	Volume	No. of trees	Volume	No. of trees	Volume	No. of trees	Volume
			Bd. ft.		*Bd. ft.*		*Bd. ft.*		*Bd. ft.*		*Bd. ft.*
Fish Creek Forks						1	1,820	2	3,800	3	5,620
McCrea Park				1	2,290	1	980	1	420	3	3,690
Longpre Cabins				7	3,310	3	560	4	1,630	14	5,500
Fishtrap Creek				2	100	1	920	2	560	5	1,580
Little Thompson River				4	750	4	2,410			8	3,160
North Fork Little Thompson River				3	1,890	5	2,620	6	5,780	14	10,290
Pleasant Valley				1	760			1	420	2	1,180
Jake Little Ranch						1	340	2	6,730	3	7,070
Lost Prairie				1	1,910					1	1,910
Lake McGregor				1	50					1	50
Little Bitterroot River				3	2,070	2	1,820	4	2,450	9	6,340
Loon Lake		1	220	1	260	2	910	3	1,840	7	3,230
Rexford				1	480			2	1,200	3	1,680
Bear Creek Saddle						2	2,090	2	800	4	2,890
Overwhich Creek				2	1,720	1	420	1	860	4	3,000
Lincoln						2	4,530	1	1,390	3	5,920
Piquett Creek	B[5]			3	420	2	900	1	980	6	2,300
	D[5]			1	1,160	2	960			3	2,120
	G[5]			2	1,940	5	4,820	4	3,690	11	10,450
	J[5]			3	2,130	12	11,760	1	110	16	14,000
	O[5]			1	1,640	3	3,910	2	1,340	6	6,890
	Q[5]			1	1,640	4	2,030	1	820	6	4,490
Total		1(0.8)	220(0.2)	38(28.8)	24,520(23.7)	53(40.1)	43,800(42.4)	40(30.3)	34,820(33.7)	132(100)	103,360(100)

[1]See table 1 for timbered acreage and table 9 for years of record.
[2]Normally cut for bark beetle control in sanitation-salvage cuttings.
[3]Percent of total number of trees shown in parentheses.
[4]Percent of total volume shown in parentheses.
[5]Control plots.

Entomologists have used mortality ratios as a device to determine the relative susceptibility to beetle infestation of ponderosa pine trees in different tree classifications or risk ratings (Keen 1943; Keen and Miller 1960). The ratios are derived by dividing the percentage of trees killed in a given risk rating by the percentage of occurrence of all trees, living and dead, in this rating. Using data from 22 undisturbed study plots in table 5 and from table 10, mortality ratios indicate that Risk 3 trees are likely to be killed by bark beetles 2.77 times as often as the average tree in the plot stands and Risk 4 trees 22.47 times as often (table 12).

Table 12.--*Relative susceptibility of risk rated ponderosa pine trees to bark beetle infestation in western Montana as indicated by mortality ratios based on tree volumes for the period 1948-1968*

Risk ratings	Percentage of occurrence		Mortality ratios[1]
	Living and dead trees	Beetle-killed trees	
1 (Low)	11.7	0.2	0.02
2 (Moderate)	71.5	23.7	.33
3 (High)	15.3	42.4	2.77
4 (Very high)	1.5	33.7	22.47
3 and 4 combined	16.8	76.1	4.53

[1]Values greater than 1.00 indicate susceptibility to beetle attack; values less than 1.00 indicate resistance to beetle attack.

DISCUSSION AND CONCLUSIONS

An average loss of 15.5 board feet per acre per year from attacks of *Dendroctonus* bark beetles underscored the endemic nature of these insect pests throughout the duration of the study. At this low level of timber losses, the "bark beetle problem" must certainly not have been of much concern to forest managers in western Montana during the period from 1948 through 1968. Furthermore, the almost continuous endemic infestations did not contribute as much as they might have to a meaningful test of the Ponderosa Pine Risk Rating System here. This would have required a much greater quantity of beetle-killed ponderosa pine trees than the sluggish infestations produced for the study.

Some questions, therefore, might well be asked. Will *Dendroctonus* beetles, for instance, ever be a problem in the management of mature ponderosa pine stands in western Montana or, more broadly, throughout the northern Rocky Mountain States west of the Continental Divide?[9] And, if so, can the risk rating system help to alleviate it?

To answer the first question, records of forest insect surveys in the northern Rockies document past outbreaks of the western pine beetle and the mountain pine beetle in mature stands of ponderosa pine. True, these outbreaks have not produced such devastating tree killing as have outbreaks of bark beetles in parts of the Pacific Coast States where, in 1956 in one outbreak area, pine beetles killed an average of 208 board feet of ponderosa pine per acre (Wickman and Eaton 1962). Notwithstanding, the more severe outbreaks of bark beetles in the northern Rockies have produced tree killing that caused depletion of ponderosa pine stands and interfered with orderly forest management planning and operations. Severe outbreaks of bark beetles will undoubtedly occur again in the northern Rockies as long as there are stands of mature ponderosa pine trees and as environmental conditions might change to encourage buildup of beetle populations to epizootic levels.

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[9]The western pine beetle is not found east of the Continental Divide. East of the Divide the mountain pine beetle becomes one of the primary tree-killing pests of the Rocky Mountain form of ponderosa pine, *Pinus ponderosa* var. *scopulorum* Engelmann. The ecology of this latter pest-host relationship is entirely distinct from that being reported here.

It appears likely that forests of mature ponderosa pine will be present for many years; some will include remnants, perhaps, of today's old-growth pine stands. Young pine stands will continue to mature, most assuredly, under increasingly intensive management. Segments of today's mature ponderosa pine stands are being placed in more or less reserved status in some multiple use zones as a result of the pressures exerted by a growing outdoor recreation-oriented public. These pressures are already forcing consideration of more selective cutting practices that tend to delay harvest cuttings in commercial ponderosa pine stands (Curtis and Wilson 1958).

The threat of bark beetle outbreaks in western Montana's existing forests of mature ponderosa pine is already indicated by appreciable numbers and volumes of high risk pine trees. The possibility exists that even more high risk trees might develop in some stands as the pine overstory competes for soil nutrients and moisture with increasing numbers of dense understory stands of more tolerant species (fig. 3).

As to the second question, even the meager data produced by the risk rating study point to a recognizable ability of the risk rating system to identify pine trees variously susceptible to lethal attacks of bark beetles in western Montana, if not generally throughout the northern Rocky Mountains. Assuming this capability, the rating system can do here what it has done elsewhere:

1. Identify individual pine trees susceptible or resistant in varying degrees to beetle attack.

2. Assess the risk, or hazard, of whole pine stands from the threat of beetle-caused depletion, or from the likelihood of these stands serving as breeding habitats that may support rapidly expanding beetle populations (Johnson 1949, 1951).

3. Assist forest managers to formulate plans to counter the threat of beetle depredations by giving priority for harvest cuttings or stand improvement treatments to stands with the highest beetle hazard.

4. Provide the detailed basis for sanitation-salvage cuttings to beetleproof pine stands suspected of being unusually susceptible to damage from bark beetle outbreaks (Johnson 1968).

The study has provided information on the abundance of high risk trees in a variety of pine stands. For example, it has shown that most of the stands sampled had 15 percent or more of their volume in high risk trees. From results of this study and experience gained elsewhere, we believe that this percentage figure represents an arbitrary but realistic demarcation between ponderosa pine stands that are either resistant to serious beetle attacks (those with less than 15 percent of their volumes in high risk trees) or acutely susceptible to them (stands with more than 15 percent of their volumes in high risk trees).

Like those of other similar studies, the results of this study should allay the fears of some foresters and timber operators that sanitation-salvage cuttings are universally uneconomical. Finally, economic-oriented studies have shown that harvesting of only high risk trees can be profitable and that the quality of timber removed is as good or better than that of the stand as a whole. It can be argued, of course, that some sanitation-salvage cuttings would not be economical.

In conclusion, we believe the study has provided foresters in this region with a workable basis for coping with a potentially serious insect problem--a basis soundly rooted in good silvicultural practice and responsive to the public's growing concern for operating techniques that exhibit full consideration for the total forest environment.

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